ENVIRONMENTAL EXPOSURE OF JG-PP/JCAA TEST PWAS

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Background:

The Joint Group of Pollution Prevention (JG-PP), partnered with the Joint Council on Aging Aircraft (JG-PP / JCAA) initiated the JG-PP / JCAA Lead Free Soldering Program. This project's goal is to generate critical reliability data on circuit cards manufactured and reworked with Lead Free and Tin Lead (SnPb) solders for military and space applications. In 2004, the program manufactured hardware with various electronic packages with Lead Free solders. Environmental Stress Screening testing was performed, based on MIL-STD 883. Members of the JG-PP / JCAA Lead Free Project Team include NASA, International Trade Bridge, American Competitiveness Institute, Rockwell Collins, Raytheon, Boeing, and BAE Systems.

The American Competitiveness Institute was assigned the task to perform Salt Atmosphere and Humidity Exposure Tests. The objective was to determine if Tin Silver Copper (SnAgCu) Lead Free solder joints reliability was equivalent to or better than Tin Lead (SnPb) solder joints.

Test Methods:
The samples were kept sealed in their original packaging or in a dry box prior to any exposure testing.

Board #	Description of board (finish/solder used)	Exposure testing
38	SnPb Hybrids and SnPb wire SnPb Manufactured	Humidity Exposure
39	SnPb Hybrids and SnPb wire SnPb Manufactured	Humidity Exposure
40	SnPb Hybrids and SnPb wire SnPb Manufactured	Humidity Exposure
107	SnAgCu/SnAgCu	Humidity Exposure
108	SnAgCu/SnAgCu	Humidity Exposure
109	SnAgCu/SnAgCu	Humidity Exposure
146	SnAgCuBi/SnCu	Humidity Exposure
147	SnAgCuBi/SnCu	Humidity Exposure
148	SnAgCuBi/SnCu	Humidity Exposure
35	SnPb Hybrids and SnPb wire SnPb Manufactured	Salt Atmosphere Exposure
36	SnPb Hybrids and SnPb wire SnPb Manufactured	Salt Atmosphere Exposure
37	SnPb Hybrids and SnPb wire SnPb Manufactured	Salt Atmosphere Exposure
104	SnAgCu/SnAgCu	Salt Atmosphere Exposure
105	SnAgCu/SnAgCu	Salt Atmosphere Exposure
106	SnAgCu/SnAgCu	Salt Atmosphere Exposure
143	SnAgCuBi/SnCu	Salt Atmosphere Exposure
144	SnAgCuBi/SnCu	Salt Atmosphere Exposure
145	SnAgCuBi/SnCu	Salt Atmosphere Exposure

Table 1. Description of samples tested and corresponding board number.

Humidity Exposure
The PWAs specified in Table 1 were exposed to 30^{o}C and 95% RH for five 48-hour cycles per MIL-STD-810F Method 507.4. The PWAs were tested for continuity prior to and after exposure as per instructions from the customer (Figures 1 & 2.).

Salt Fog Exposure
The PWAs specified in Table 1 were exposed to a 48 hour Salt Spray Atmosphere as per ASTM B117 and the agreement with the customer. Given the number of samples it was necessary to do two sets of exposures with board types being intermingled. The PWAs were tested for continuity prior to and after exposure as per instructions from the customer (Figures 1 & 2.).

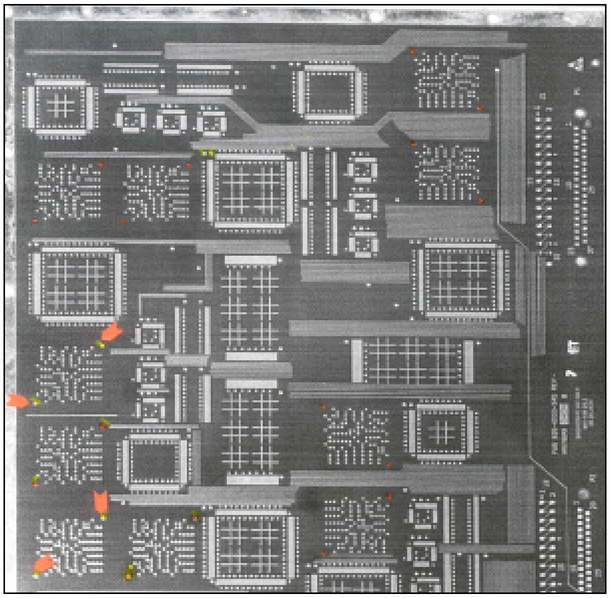

Figure 1. Test board with arrows for continuity check of CT-BGAs, bottom side.

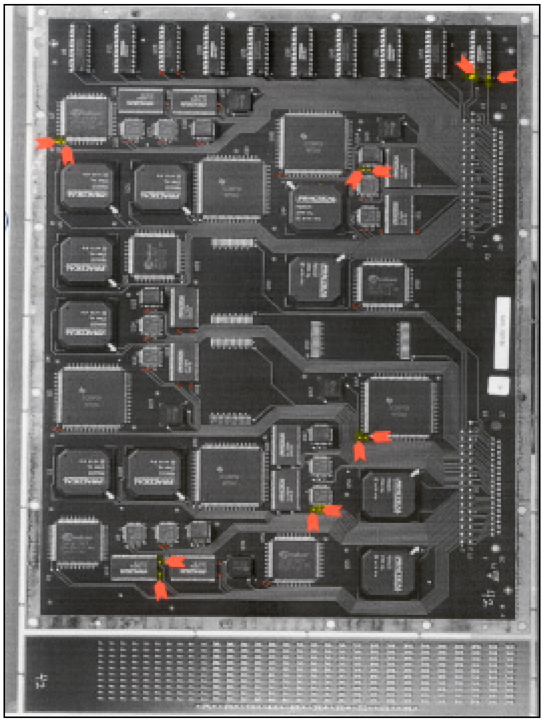

Figure 2. Test board continuity check, top side.
Points indicate where continuity tests were performed

Results:

Board #	Component Number	Exposure Testing
38	U49	Humidity Exposure
108	U44*	Humidity Exposure
104	U35	Salt Atmosphere Exposure
104	U56*	Salt Atmosphere Exposure
105	U3	Salt Atmosphere Exposure

Table 2. Components that failed continuity testing after environmental conditioning.
*Note: These components failed continuity testing prior to environmental testing

Board 38: Component U49

? There was an open found between the ninth and tenth pins on the component. Those two pins were supposed to be shorted within the component.

? The open circuit was caused by a broken bond within the chip. This can be seen in the X-ray images (Figures 3 and 4).

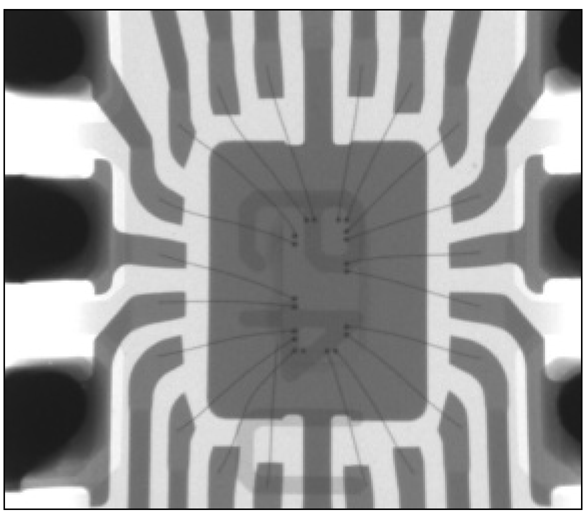

Figure 3.

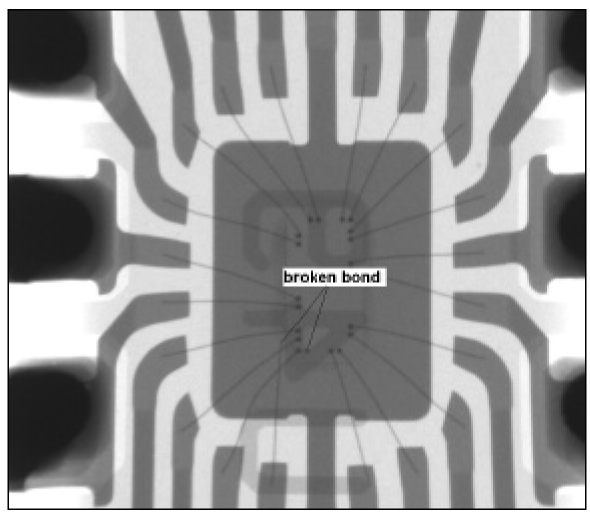

Figure 4.

Board 108: Component U44

? Continuity testing showed that there is an open within the component after salt exposure. The location of the open circuit was identified but the root cause could not be determined.

Board 104: Component U35

? Component U35 showed open circuits where the component leads were supposed to be in series (daisy chained). X-ray analysis of this component revealed die with no internal wire bonds to the lead frame. Figure 5 is an X-ray image of the component showing no internal wire bonds. Figure 6 is the same component on board number 105 showing wire bonds properly attached to the die.

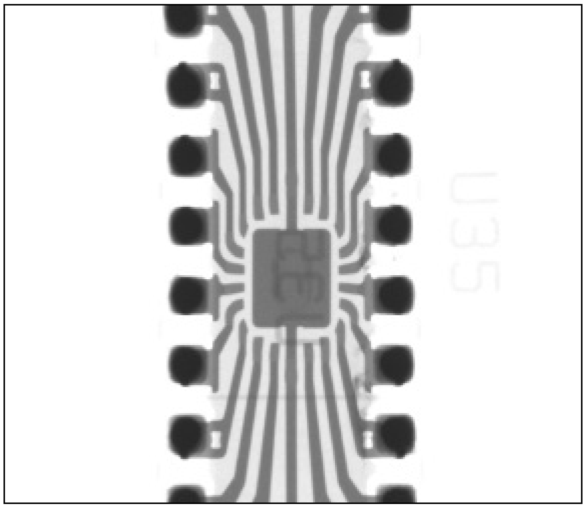

Figure 5.

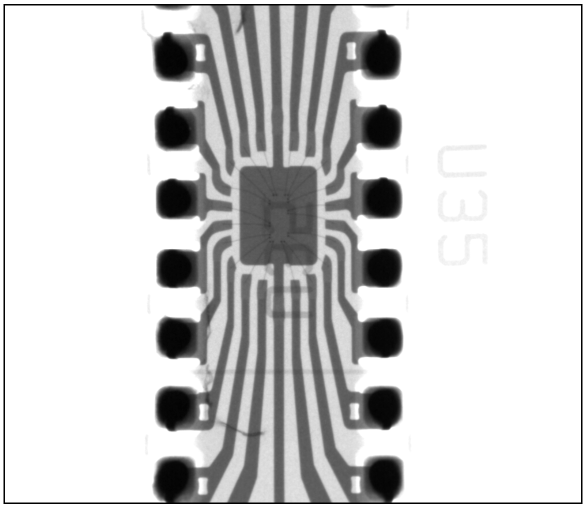

Figure 6.

Board 104: Component U56

? Continuity testing prior to and after the salt atmosphere exposure showed that there was an open circuit within the component (Figure 7). The location of the open circuit was identified between the two via locations marked with red arrows on Figure 8. The two should be electrically connected through the 3 BGA balls marked with blue arrows in Figure 8. Figure 9 is an image of the questionable area of component U56. There is a significant amount of voiding which may contribute to the open circuit. Figure 10 is an image of U55, a properly working component of the same model on the same board. There are significantly less voids in the solder in this component than on U56.

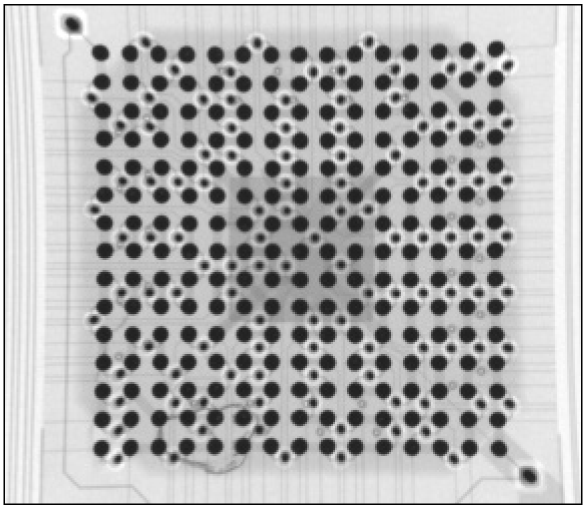

Figure 7.

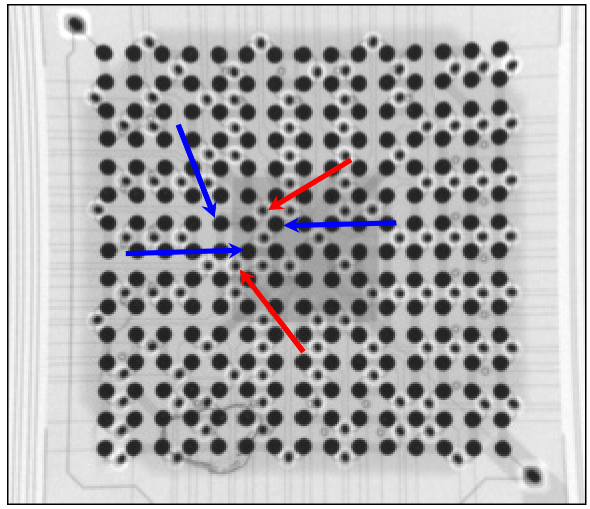

Figure 8.

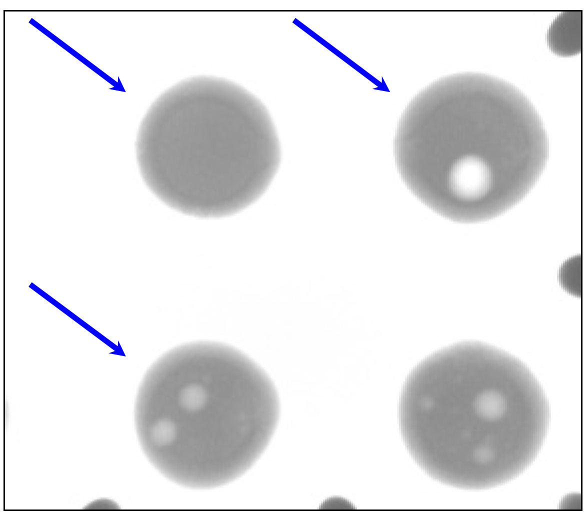

Figure 9.

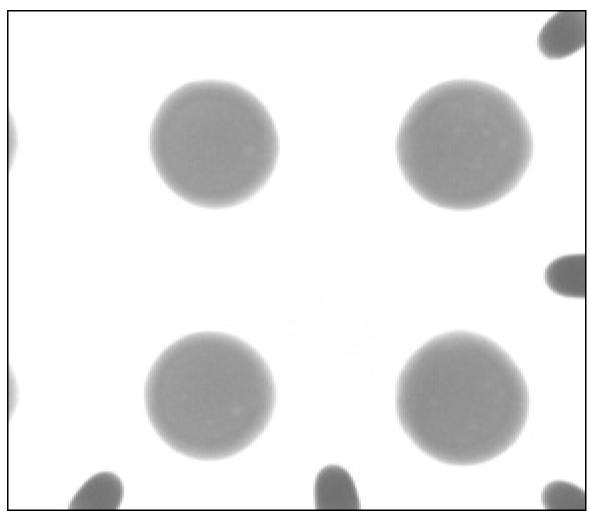

Figure 10.

Board 105: Component U3

- ? There was a resistance reading of 70.6 O across the terminals of the component indicating an improperly wired component.

- ? The X-ray images show what could be solder thickness issues of the legs on the board as they seem to change throughout the whole part.

  - Figure 11: (60kV 50µA) Board 105 debris U3 bottom left corner top down
  - Figure 12: (60kV 50µA) Board 105 debris U3 bottom right corner top down
  - Figure 13: (60kV 50µA 45^o + rotation 55^o Oblique) Board 105 debris U3 pin 1
  - Figure 14: (60kV 50µA) Board 105 debris U3 pin 1
  - Figure 15: (60kV 50µA) Board 105 debris U3 upper right corner top down
  - Figure 16: (60kV 50µA 45^o + rotation 55^o Oblique) Board 105 debris U3 upper right corner
  - Figure 17: (60kV 50µA 45^o + rotation 55^o Oblique) Board 105 debris U3

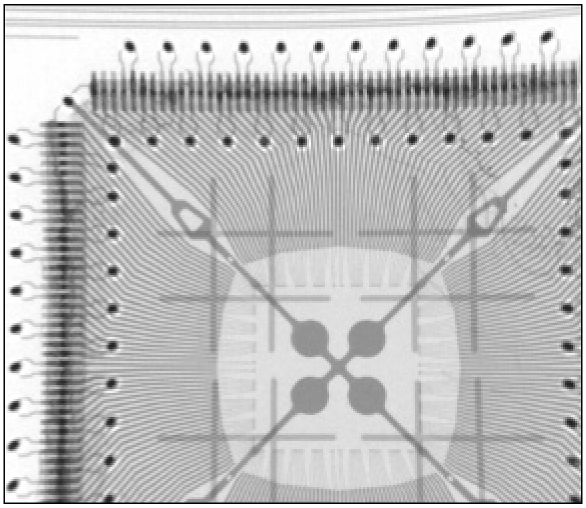

Figure 11.

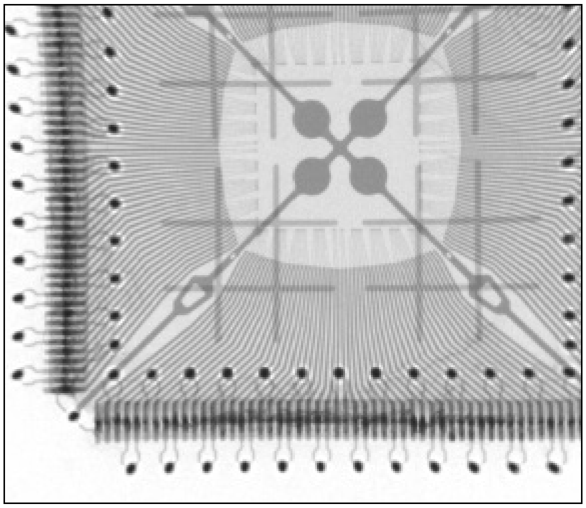

Figure 12.

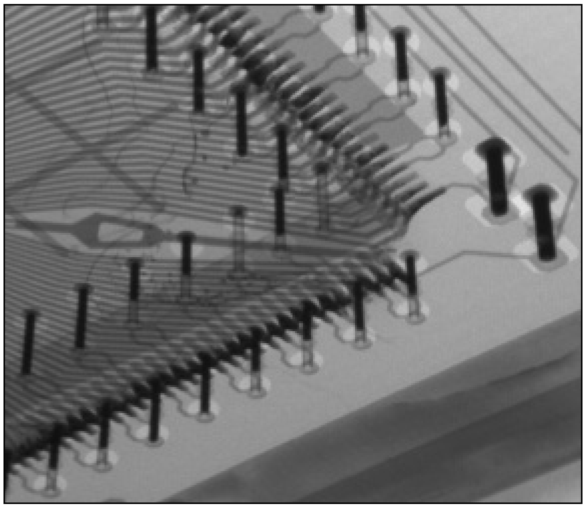
Figure 13.

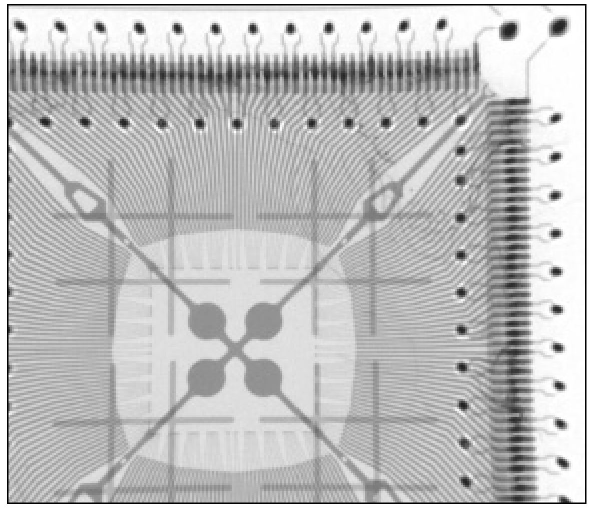
Figure 14.

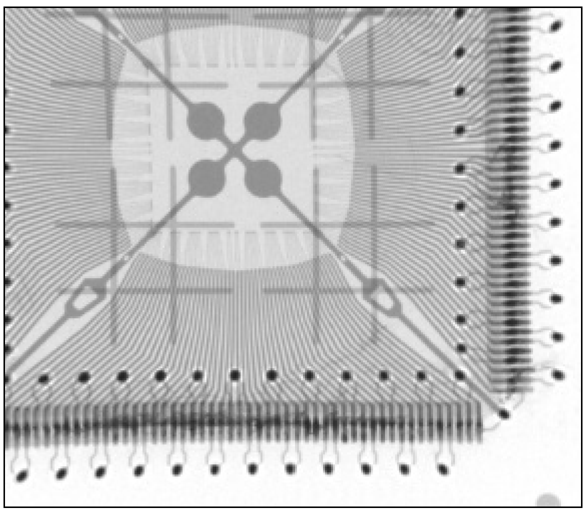
Figure 15.

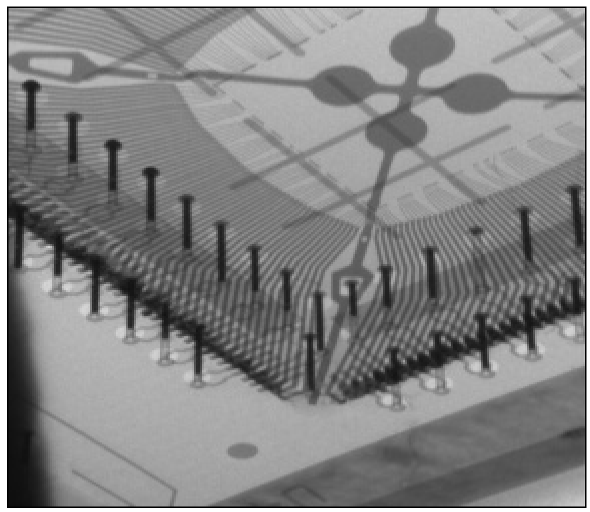
Figure 16.

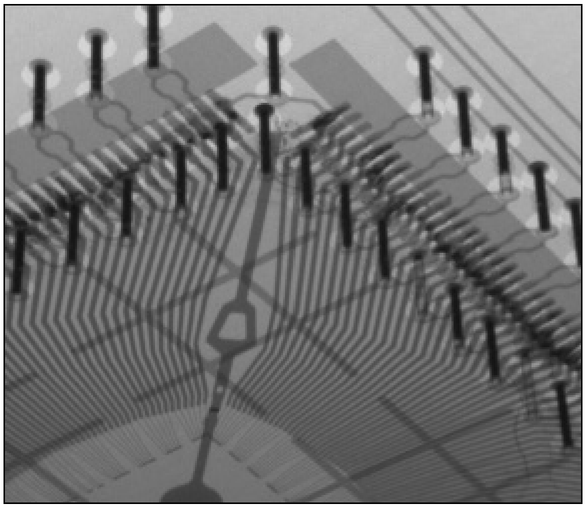

Figure 17.

Optical images of the failed components after salt atmosphere exposure

NOTE: Only the salt fog exposed assemblies are displayed as the thermally stressed units did not indicate any visual evidence of damage.

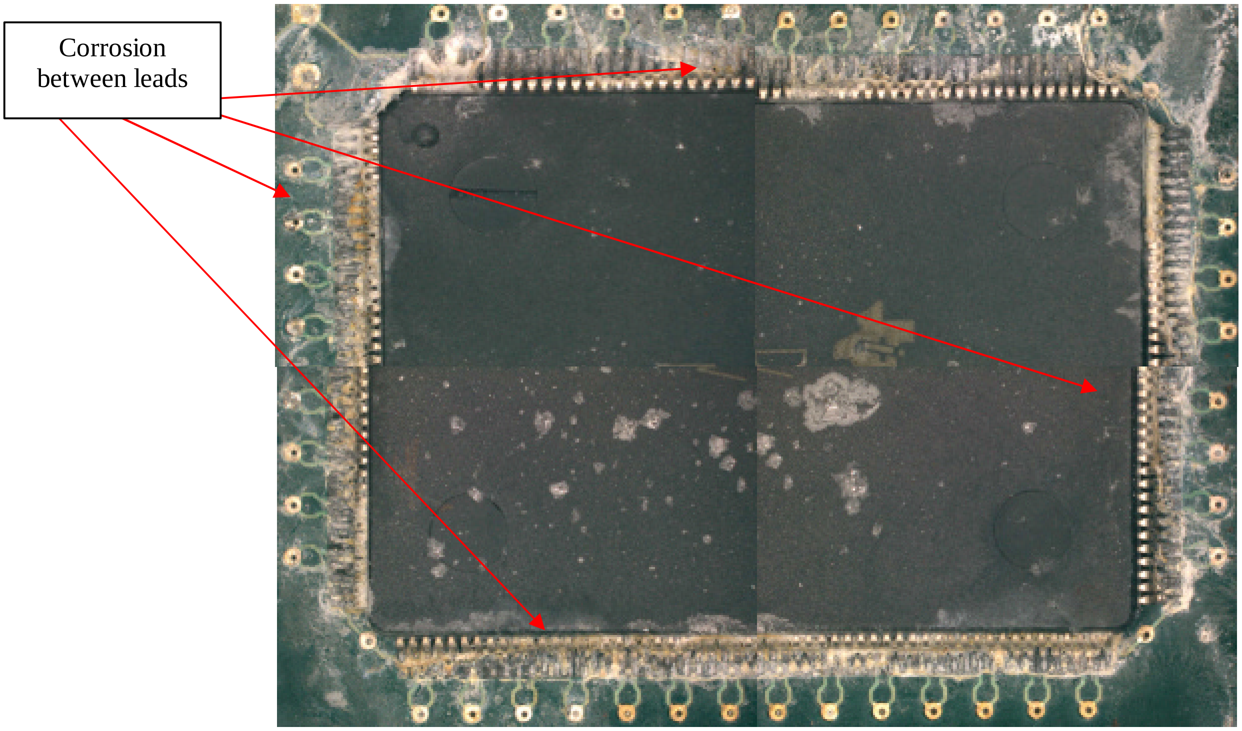

Figure 18. Optical image of QFP U3 from board 105 at 7X.

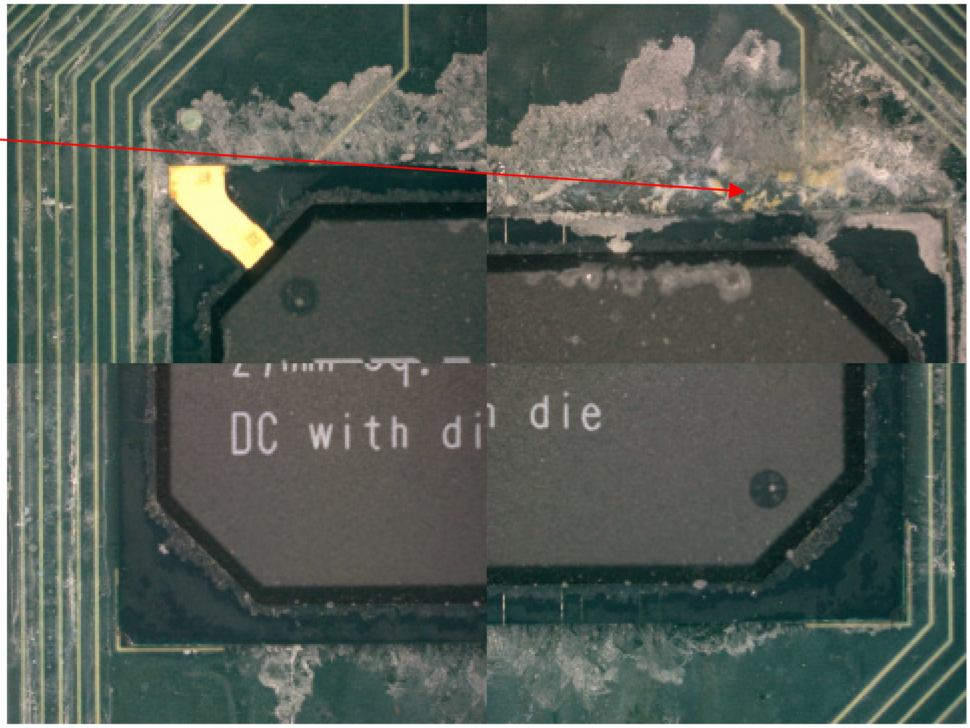

Figure 19 Optical image of BGA U56 from board 104 at 7X.

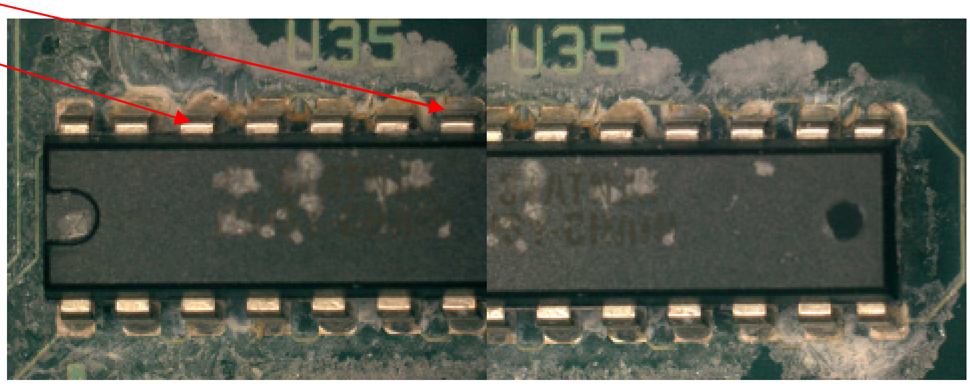

Figure 20 Optical image of SOIC U35 from board 104 at 7X.

Conclusions:

There were a total of five continuity failures from the group of points tested (Table 3). The following is a summary of the failure analysis performed:

Board 38: Component U49: The open circuit was caused by a broken bond within the chip.

Board 108: Component U44: Continuity testing showed that there is an open within the component after salt exposure.

Board 104: Component U35: Open circuits where the component leads were supposed to be in series (daisy chained).

Board 104: Component U56: Continuity testing prior to and after the salt atmosphere exposure showed that there was an open circuit within the component.

Board 105: Component U3: There was a resistance reading of 70.6 O across the terminals of the component indicating an improperly wired component.

All other components passed Humidity Exposure and Salt Atmosphere testing.

Based on the components and boards tested, the Tin Lead (SnPb) solder joints and the Tin Silver Coppers (SnAgCu) solder joints were not the root cause of failure. It was determined that the failures were cause by packaging or wiring defects. Based on the Salt Atmosphere and Humidity Exposure tests performed, Tin Silver Copper (SnAgCu) Lead Free solder joints reliability was equivalent to Tin Lead (SnPb) solder joints.

Board #	Solder Alloy	Component Number	Exposure Testing
38	SnPb	U49	Humidity Exposure
108	SnAgCu	U44*	Humidity Exposure
104	SnAgCu	U35	Salt Atmosphere Exposure
104	SnAgCu	U56*	Salt Atmosphere Exposure
105	SnAgCu	U3	Salt Atmosphere Exposure

Table 3. Components that failed continuity testing after environmental conditioning.
*Note: These components failed continuity testing prior to environmental testing

Visual inspection of failed salt atmosphere components exhibited corrosion between the leads. This level of corrosion was consistent between all boards and components.

Customer Service Survey

As the National Electronics Manufacturing Center Of Excellence, we are constantly striving to better serve our customers. In order to meet this goal, we would value your input on our performance. At your convenience, please fill out the following survey questions and fax it back to (610) 362-1289. Thank You.

Customer Name ______________________ Title ______________________

Company Name ______________________ Date ______________________

Project/Service ______________________

☐ Mfg. ☐ Failure Analysis ☐ Materials Qualification ☐ Other__________

Please rate the following categories on a scale of 0 - 10 — Circle only one number per line:

0 = Lowest Score, 0 = Strongly Disagree; 5 = Average Score, 5 = Neutral; 10 = Highest Score, 10 = Strongly Agree

Job or service was completed to your satisfaction.	0	1	2	3	4	5	6	7	8	9	10
ACI met your needs and expectations.	0	1	2	3	4	5	6	7	8	9	10
Job or service was delivered on time.	0	1	2	3	4	5	6	7	8	9	10
Your materials were returned in proper condition.	0	1	2	3	4	5	6	7	8	9	10
I am confident in the results of the ACI service.	0	1	2	3	4	5	6	7	8	9	10
It was easy to order services from ACI.	0	1	2	3	4	5	6	7	8	9	10
The report was accurate and easy to understand.	0	1	2	3	4	5	6	7	8	9	10
ACI personnel kept me informed during the service.	0	1	2	3	4	5	6	7	8	9	10
I would recommend ACI to a colleague.	0	1	2	3	4	5	6	7	8	9	10
I would use ACI's services in the future.	0	1	2	3	4	5	6	7	8	9	10
ACI compares favorably to its competitors.	0	1	2	3	4	5	6	7	8	9	10

How did you first learn of ACI's services?

☐ Internet ☐ Mail ☐ EMPFasis ☐ Colleague ☐ Other ______________________

I annually specify or influence the purchase of equipment, materials, products and/or services that cost:

☐ Over \$1M ☐ \$500K-\$1M ☐ \$100K-\$500K ☐ \$10K-\$50K ☐ Under \$10K

What other services can ACI provide for you?

☐ Training ☐ Lab Services ☐ Mfg. Services ☐ Engineering ☐ Other ______________________

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